

Method of estimating a downlink channel

The present invention concerns in general terms a method of estimating a channel in a mobile telecommunication system and more particularly a method of downlink channel estimation by a base station.

In a mobile telecommunication system, a base station transmits signals to mobile terminals and receives them from them. The transmission channels from the base station to the mobile terminals are called downlink channels and conversely the transmission channels from the mobile terminals to the base station are called uplink channels. Each transmission channel, uplink or downlink, comprises a variety of paths between a transmitter and a receiver, each path being characterised by a delay, a direction of arrival, an attenuation and a phase rotation. The effect of the attenuation and phase rotation can be modelled simply by a complex multiplicative coefficient characteristic of the path.

It is known that an array of antenna can be used for forming beams and/or for cancelling interference in one or more directions. The antenna processing consists of a weighting of the outputs of the different antennae by complex coefficients followed by an adding of the weighted outputs, the coefficients being chosen so as to obtain the required equivalent antenna diagram. It is thus possible to form a beam in the directions of arrival of the useful signal whilst placing zeros in the directions of arrival of the interfering signals. Beam formation (also referred to as channel formation), has been applied to mobile telephony, notably in order to direct a reception beam from a base station to a mobile terminal (up link). The base station is then equipped with an adaptive antenna (referred to as an "intelligent antenna") capable of pointing in the directions of arrival of the paths of propagation of a signal transmitted by a mobile terminal.

When a mobile telephony system functions according to a code division multiple access (CDMA) mode, the signals coming from the different mobile terminals are separated by filterings adapted to the signatures of the different users. The signatures employed must have good correlation properties, namely low intercorrelation values and a very pronounced autocorrelation peak.

The first of these two characteristics makes it possible to separate the signals coming from the different users. Naturally, in practice, this separation is not perfect and depends on a factor of orthogonality between the different transmission channels.

The second characteristic makes it possible amongst other things to separate in time the correlation peaks output from the adaptive filtering and therefore to isolate

the signals of a user being propagated on different paths. In order to improve the signal to noise ratio, the diversity of paths can be exploited by combining these signals in a rake receiver. The complex coefficients used in the different branches of the receiver are chosen so as to be equal to the conjugates of the complex multiplicative coefficients introduced by the paths concerned. To this end, the receiver effects an estimation of the uplink channel. In practice, it determines, by means of pilot symbols transmitted by the mobile terminal, the coefficients of attenuation and the phase rotations undergone by the signal along the paths constituting the channel. The resulting filtering operation is a filtering adapted to the equivalent filter of the channel.

In addition to the uplink channel estimation, it may be advantageous to have available at the base station an estimation of the downlink channel. This is because the base station can then transmit, in the direction of the uplink paths, signals precompensated for phase so that they are in phase again at the mobile terminal. Such a precompensation has the advantage of improving the signal to noise ratio on reception.

In order to have an estimation of the downlink channel at the base station, it can be envisaged estimating this at the mobile terminal and transmitting the estimate obtained to the base station. However, when the channel exhibits rapid variations in its transfer function, for example when the mobile terminal is moving rapidly, the estimation must be transmitted very frequently, which uses very significant conveying resources. Naturally, conversely, if the estimation is transmitted infrequently, the base station will not be able to follow the change in the downlink channel and will therefore not be able to correctly effect the phase precompensation.

The purpose of the invention is to propose a method of estimation of a downlink channel by the base station not requiring the transmission of a large quantity of information by the mobile terminal.

To this end, the invention is defined by a method of estimating a downlink channel by the base station and a mobile terminal in a mobile telecommunication system, according to which the said base station estimates the uplink channel between the said mobile terminal and the said base station, deduces variations in the uplink channel and those in the downlink channel, and estimates at a second instant the said downlink channel from an initial estimation at a first instant and variations in the said downlink channel between the said first and second instants.

The initial estimation of the downlink channel is for example obtained by the mobile terminal and transmitted by it to the base station.

According to a first embodiment, the estimation of the uplink channel comprises, for each propagation path (i) of the said channel, the estimation of a first complex multiplicative coefficient (c_i^n) representing the attenuation and phase rotation undergone by a signal at a first frequency (f_u) propagating along the said path and the estimation of the downlink channel comprises, of each of the same paths, the estimation of a second complex multiplicative coefficient (c_i^d) representing the attenuation and phase rotation undergone by a signal at a second frequency (f_d) propagating along the said path.

Advantageously, for a given path (i) and a given interval of time (Δt) the variation in the second complex multiplicative coefficient (Δc_i^d) during the said interval of time is calculated from the variation in the first complex multiplicative coefficient (Δc_i^n) during the said interval of time according to: $\Delta c_i^d / c_i^d = f_d / f_u \cdot \Delta c_i^n / c_i^n$.

The second complex multiplicative coefficients (c_i^d) of the different paths can be obtained by adding over time their respective variations (Δc_i^d) and initial values ($c_i^d(0)$) transmitted by the mobile terminal.

According to a second embodiment, the estimation of the uplink channel comprises, for each direction (θ_k) belonging to a plurality (N) of directions angularly sampling a zone served by the said base station, the estimation of a first complex multiplicative coefficient (c_k^n) representing the attenuation and the phase rotation undergone by a signal at a first frequency (f_u), transmitted by the mobile terminal and arriving at the said base station substantially in the said direction, and the estimation of the downlink channel comprises, for each of the said directions (θ_k), the estimation of a second complex multiplicative coefficient (c_k^d) representing the attenuation and phase rotation undergone by a signal at a second frequency (f_d) transmitted by the said base station in this direction to the said mobile terminal.

Advantageously, for a given direction (θ_k) and a given interval of time (Δt), the variation in the second complex multiplicative coefficient (Δc_k^d) during the said interval of time is calculated from the variation in the first complex multiplicative coefficient (Δc_k^n) during the said interval of time according to: $\Delta c_k^d / c_k^d = f_d / f_u \cdot \Delta c_k^n / c_k^n$.

The second complex multiplicative coefficients (c_k^d) in the different directions can be obtained by adding over time their respective variations (Δc_k^d) and initial values ($c_k^d(0)$) transmitted by the mobile terminal.

The invention is also defined by a device for estimating a downlink channel intended to be mounted in a base station in a mobile telecommunication system and comprising means for implementing the method as just disclosed.

The characteristics of the invention mentioned above, as well as others, will emerge more clearly from a reading of the following description in relation to the accompanying figures, amongst which:

Fig 1 depicts schematically a transmission channel between a base station and a mobile terminal;

Fig 2 depicts schematically a first embodiment of the invention;

Fig 3 depicts schematically a second embodiment of the invention.

The general idea at the basis of the invention is to propose a method of estimating the downlink channel from an estimation of the uplink channel and possibly updating information transmitted by the mobile terminal.

Fig 1 depicts a transmission channel between a base station and a mobile terminal. The channel comprises a plurality of paths T_1, T_2, \dots, T_P , each path i introducing an attenuation and phase rotation of the signal S which can be modelled by a complex multiplicative coefficient $\alpha = \alpha_i \exp(jv_i + j\varphi_i)$ where α_i is the coefficient of the path i , $v_i = 2\pi f L_i / c$ is the phase rotation on the said path, L_i is the length of the path, c the speed of propagation of light, f is the frequency used, and φ_i is the polarisation of the incident signal.

It will be assumed hereinafter that the paths of the uplink channel are identical to those of the downlink channel. The signal received by the base station and the one received by the mobile terminal are then expressed respectively by:

$$R_u = \left[\sum_{i=1}^P \alpha_i \exp - j(2\pi f_u L_i / c + \varphi_i) \right] S_u \quad (1)$$

$$R_d = \left[\sum_{i=1}^P \alpha_i \exp - j(2\pi f_d L_i / c + \varphi_i) \right] S_d \quad (2)$$

where S_u and R_u are respectively the signal transmitted and the signal received over the up link,

S_d and R_d are respectively the signal transmitted and the signal received over the down link,

f_d and f_u the frequencies used respectively on the down link and the up link. The complex multiplicative coefficients relating to the path i of the uplink channel and downlink channel respectively will be denoted $c_i^u = \alpha_i \exp - j(2\pi f_u L_i / c + \varphi_i)$ and $c_i^d = \alpha_i \exp - j(2\pi f_d L_i / c + \varphi_i)$.

Fig 2 illustrates a base station receiver accordingly to a first embodiment of the invention. The device comprises an array of antennae $(20_1), \dots, (20_L)$, for example a linear array or a uniform circular array, each antenna output being filtered by a battery of filters $(21_1), \dots, (21_P)$ adapted to the signature of the user and to the different paths $i=1..P$. The output signals of the filters corresponding to one and the same path i are weighted and added in channel formers $(22_1), \dots, (22_P)$. The channel formers (22_i) form beams in the directions of arrival of the paths $i=1..P$. To do this, they receive from the estimators $(23_1), \dots, (23_P)$ the estimated values, θ_i , of the directions of arrival of the different paths. The outputs of the channel formers are then subjected to a combination (MRC) in a rake filter (29). An estimation of the complex multiplicative coefficients, c_i^u , relating to the different paths of the uplink channel is effected by path estimators $(24_1), \dots, (24_P)$ receiving the output signals from the channel formers $(22_1), \dots, (22_P)$. The multiplicative coefficients c_i^u can, for example, be determined conventionally by means of pilot symbols transmitted by the mobile terminal. Advantageously, the estimation of the multiplicative coefficients and the directions of arrival will be effected conjointly, as described in French present application n° 00 11160 filed on 29.08.2000 in the name of applicant. The coefficients c_i^u are transmitted to differentiating filters $(25_1), \dots, (25_P)$ and their complex conjugates to the rake filter (29). The differentiating filters (25_i) calculate respectively:

$$\Delta c_i^u = \frac{\partial c_i^u}{\partial t} \Delta t = \left[\frac{\partial \alpha}{\partial t} \exp(-j(2\pi f_0 L/c + \phi)) - j \cdot (2\pi f_0 L/c) \cdot c_i^u \cdot \frac{\partial L}{\partial t} \right] \Delta t \quad (3)$$

where Δt is the interval of time between two consecutive estimations c_i^u ,
an expression which can be approximated by:

$$\Delta c_i^u \approx -j \cdot (2\pi f_0 L/c) \cdot c_i^u \cdot \frac{\partial L}{\partial t} \Delta t \quad (4)$$

if it is considered that the coefficients of attenuation on the different paths vary little during the interval of time Δt . These values are divided as $(26_1), \dots, (26_P)$ by the complex coefficients c_i^u and then multiplied by the coefficient f_d/f_0 as $(26'_1), \dots, (26'_P)$ and transmitted to the integrators $(27_1), \dots, (27_P)$. These integrators make the following calculation:

$$c_i^d(t + \Delta t) = c_i^d(t) (1 + \eta_i(t) \cdot \Delta t) \quad (5)$$

where $\eta_i(t)$ is the output of the multiplier (26_i) and $c_i^d(0)$ are P initial values transmitted by the mobile terminal. In order to avoid any difference due to integration, an estimation of the c_i^d values is effected and transmitted at regular intervals by the mobile terminal, the integrators (27_i) being reinitialised at each

refreshing. The refresh frequency is chosen so that as to be sufficient although not to give rise to an excessively high transmission rate on the up link.

This gives:

$$\Delta c_i^d = -j \cdot (2\pi f_d L/c) \cdot c_i^d \cdot \frac{\partial L}{\partial t} \Delta t \quad (6)$$

The values c_i^d are transmitted to a phase precompensation and channel formation module (28). This module calculates, from a signal S_d to be transmitted over the downlink channel, phase-precompensated signals $c_i^{d*} \cdot S_d$. Each precompensated signal $c_i^{d*} \cdot S_d$ is then weighted by antenna coefficients so as to form a transmission beam in the direction θ_i of the corresponding incident path. If it is assumed that the paths of the downlink channel are identical to those of the uplink channel, the precompensated signals arrive in phase at the mobile terminal, which improves the signal to noise ratio on reception.

Fig 3 illustrates a base station receiver according to a second embodiment of the invention. The device comprises an array of antennae $(30_1), \dots, (30_N)$ and a channel former (32) forming beams in N directions angularly sampling a zone served by the base station, for example, for a linear network, in the equidistributed directions $\theta_k = k \cdot \pi/N$, $k=0, \dots, N-1$. The uplink channel can be modelled by a vector with N components $\vec{C}^u = (c_0^u, c_1^u, \dots, c_{N-1}^u)^T$ where $c_k^u = \alpha_k \cdot \exp[-j(2\pi f_u L_k/c + \varphi_k)]$ if the channel has a path of length L_k in the direction θ_k and $c_k^u = 0$ otherwise. Likewise, the downlink channel can be modelled by a vector $\vec{C}^d = (c_0^d, c_1^d, \dots, c_{N-1}^d)^T$ where $c_k^d = \alpha_k \cdot \exp[-j(2\pi f_d L_k/c + \varphi_k)]$ and $c_k^d = 0$ with the same convention. The N outputs of the channel former (32) are supplied to a channel estimation module (34) estimating the components of the vector \vec{C}^u . The components of this vector are then transmitted to a differentiating filter (35) evaluating the variation in the vector \vec{C}^u during the time interval Δt separating two consecutive estimations. The variation in this vector can be written $\vec{\Delta C}^u = (\Delta c_0^u, \Delta c_1^u, \dots, \Delta c_{N-1}^u)^T$ where $\Delta c_i^u = -j \cdot (2\pi f_u L/c) \cdot c_i^u \cdot \frac{\partial L}{\partial t} \Delta t$ with the same assumption as that made at (4). The vector $\vec{\Delta C}^u$ is then multiplied at (36) by the matrix $\mathbf{M} = \text{Diag}(f_d/f_u, 1/c_i^u)$. The vector thus obtained, $\vec{\Delta C}^d$, is transmitted to an integrator (7) which performs the calculations of the components c_k^d of the vector \vec{C}^d by: $c_k^d(t + \Delta t) = c_k^d(t) + \gamma_k(t) \cdot \Delta t$. The integrator is regularly reinitialised with a refresh vector $\vec{C}^d(0)$ whose non-zero components are the estimations c_k^d supplied by the mobile terminal in the path directions θ_k . The vector \vec{C}^{d*} of the conjugate components

c_k^{d*} is then transmitted to a phase precompensation and channel formation module in the directions θ_k . In similar manner to the previous embodiment, this module calculates, from a signal S_d to be transmitted over the downlink channel, phase-precompensated signals $c_k^{d*}.S_d$. Each precompensated signal $c_k^{d*}.S_d$ is then weighted by antenna coefficients so as to form a transmission beam in the direction θ_k .

The device described above has been depicted, for reasons of simplicity, in the form of functional modules. It goes without saying, however, that the various functions can be executed by a processor programmed for this purpose or by a plurality of dedicated processors.